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## ORIGINAL ARTICLE

# Reproducibility and reliability of subscapularis tendon assessment using CT-arthrography

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### KEYWORDS

Subscapularis;  
Computed  
tomography;  
Reliability;  
Rotator cuff imaging

### Summary

**Background:** Computed tomography (CT) coupled with arthrography remains the reference standard for the preoperative evaluation of rotator cuff tears. The objectives of this study were to evaluate intra-observer and inter-observer reproducibilities of CT-arthrographic assessment of the subscapularis tendon and to assess the validity and reliability of this investigation.

**Hypothesis:** CT-arthrography is reliable and reproducible for the preoperative characterisation of subscapularis tendon lesions.

**Material and methods:** We retrospectively reviewed 67 shoulders with rotator cuff tears in one or more tendons managed by arthroscopy, both to confirm the diagnosis and to allow therapeutic interventions. Each of the 67 preoperative CT-arthrograms was evaluated by three readers, of whom the first two evaluated the images twice at an interval of 30 days. The following were recorded at each reading: partial- or full-thickness tear in one or more rotator cuff tendons, intra-tendinous delamination, tendon stump retraction, and fatty degeneration of the muscles. The position of the long head of biceps tendon was assessed. A statistical analysis was performed using Fleiss' method to compute intra-observer and inter-observer variabilities in CT-arthrography assessment of the subscapularis tendon status. Validity of this assessment was measured by computing the concordance coefficients between CT-arthrography and arthroscopy.

**Results:** Specificity of CT-arthrography was satisfactory for assessing the subscapularis tendon. Sensitivity was low. Significant inter-observer and intra-observer variabilities were documented. The concordance coefficients between CT-arthrography and arthroscopy indicated that major differences were common with all three readers. When assessing the subscapularis tendon by CT-arthrography, all readers experienced difficulties in distinguishing intact tendons, delaminated tendons, and tendons with tears confined to the upper third.

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*Discussion:* Although CT-arthrography remains the reference standard for the preoperative investigation of rotator cuff tears, significant variability occurs in assessing the continuity of the subscapularis tendon. Reliability of this assessment is not optimal, as shown by our evaluation of concordance with arthroscopy. Although our data should be interpreted in the light of the investigation and measurement biases present in our study, they suggest that CT-arthrography may fail to provide a valid and reproducible assessment of the subscapularis tendon. The development of magnetic resonance (MR) imaging and MR-arthrography will probably improve the preoperative evaluation of subscapularis tears in the near future.

*Level of evidence:* Level III; diagnostic value study.

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## Introduction

Isolated subscapularis tendon tears were first described in 1954 by Hauser [1,2]. Although the subscapularis plays a pivotal role in overall shoulder function and, more specifically, in rotator cuff function, it long received limited attention in orthopaedic and radiological publications. More recently, the development of arthroscopic shoulder surgery prompted studies of outcomes after reparative procedures for isolated or combined subscapularis tendon tears [3–9].

The clinical and radiographic diagnosis of subscapularis tendon tears remains challenging [10,11]. An accurate preoperative diagnosis, most notably via computed tomography (CT) coupled with arthrography of the glenohumeral joint, is crucial, as it influences intraoperative decisions regarding strategies and techniques. At present, CT-arthrography of the glenohumeral joint is the reference standard for the preoperative assessment of rotator cuff tears, despite the growing popularity of magnetic resonance imaging (MRI) for evaluating shoulder disorders.

The objectives of this study were to measure the intra-observer and inter-observer reproducibility of CT-arthrography for assessing the subscapularis tendon and to evaluate the reliability and validity of CT-arthrography for diagnosing subscapularis tendon tears. To this end, we assessed the level of agreement between CT-arthrography and arthroscopy.

## Material and methods

### Study patients

We retrospectively assessed 67 shoulders in 67 patients (no bilateral cases), 38 women and 29 men with a mean age of 58 years (range, 32–78 years). All patients had clinical, radiological, and CT-arthrographic findings consistent with tears in one or more rotator cuff tendons. The symptoms were refractory to pharmacotherapy and physical therapy. Arthroscopy of the shoulder was performed to determine whether the suspected lesions were present and to conduct any appropriate therapeutic interventions. In all patients, arthroscopy showed partial- or full-thickness tears in one or more rotator cuff tendons.

### Surgical procedure

Arthroscopy was performed under general anaesthesia with the patient in the beach-chair position. In all patients, a

posterior portal was created through the soft point and used to introduce the arthroscope into the glenohumeral joint cavity. The entire joint was assessed in a systematic manner before any intervention was performed. Special attention was directed to the following:

- presence of a partial- or full-thickness tear in at least one of the three rotator cuff tendons, to determine whether the patient met criteria for inclusion in the study;
- appearance of the subscapularis tendon both in the neutral position and in internal rotation to expose the entire tendon footprint on the lesser tuberosity;
- appearance of the biceps pulley for the long head of the biceps tendon (LHBT) in the bicipital groove;
- position, trajectory, and appearance of the LHBT in neutral rotation and detection of LHBT instability during alternating internal and lateral rotation.

The arthroscopic assessment was filmed using a digital camera incorporated in the arthroscopy system.

The following therapeutic interventions were performed: combined acromioplasty and tenotomy ( $n=50$ ), including 33 with concomitant supraspinatus tendon reattachment; isolated tenotomy ( $n=4$ ), isolated subscapularis tendon reattachment ( $n=12$ ) and isolated acromioplasty ( $n=1$ ).

## Evaluation methods

The CT-arthrogram was used to assess the rotator cuff, to detect partial- and full-thickness tears in one or more tendons with or without intra-tendinous delamination, to determine the tendon retraction stage, and to evaluate fatty degeneration of the muscles according to Bernageau and Goutallier [12]. LHBT position was also assessed. The 67 CT-arthrograms were each read by three different physicians, a senior orthopaedic surgeon, an orthopaedic surgery resident, and a senior radiologist specialised in osteoarticular imaging. The two orthopaedic surgeons read each CT-arthrogram twice, at an interval of 30 days. The radiologist performed a single reading of each CT-arthrogram.

The 67 arthroscopy films were reviewed and, based on the results, the subscapularis tendon was classified as continuous and intact, split (intra-tendinous delamination and/or fraying of the upper edge and/or fraying of the deep surface), having a full-thickness tear confined to the upper third, having a full-thickness tear confined to the upper two-thirds, or having a full-thickness tear involving the entire height of the tendon. When a tear was found, retraction was

**Table 1** Interpretation of the reliability coefficient R0.

Reliability coefficient	$R0 > 0.9$	$0.9 < R0 < 0.7$	$0.7 < R0 < 0.5$	$0.5 < R0 < 0.3$	$R0 < 0.3$
Interpretation	Very good	Good	Fair	Poor	Very poor

described as absent, to the anatomic neck of the humerus, or to the glenohumeral joint space.

### Statistical analysis

Intra-observer reproducibility and variability was assessed based on the two readings of each CT-arthrogram performed by each of the two orthopaedic surgeons. Fleiss' kappa was computed to assess agreement between the two readings made by the same physician. The Fermanian concordance coefficient (R0) was used to assess reliability.

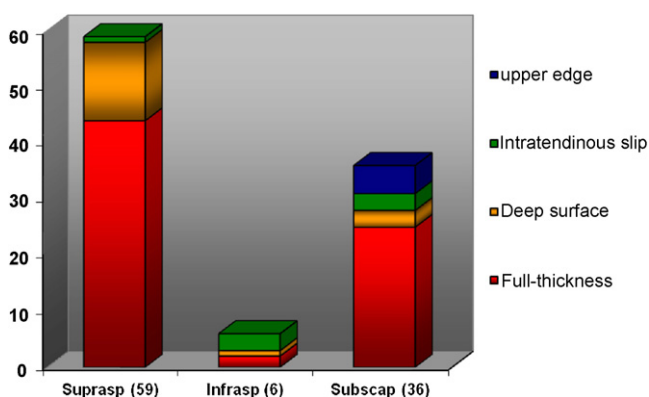
Inter-observer reproducibility was assessed using the readings by all three physicians. Fleiss' kappa was computed and the concordance coefficient was determined.

We tested qualitative variables (partial- or full-thickness tears in the subscapularis tendon). To allow a reliable assessment of the data, the kappa test was performed using three modalities, by dividing the 67 cases into three groups, as follows: intact continuous subscapularis tendon, delaminated subscapularis tendon, and torn tendon (upper third, upper two-thirds, or entire height).

### Distribution of the patients and tendon lesions

Of the 67 patients, 36 had subscapularis tears and 31 did not. The patients without subscapularis tears had either isolated supraspinatus tears ( $n=27$ ) or tears involving both the supraspinatus and infraspinatus ( $n=4$ ). Among the 36 patients with subscapularis tears, eight had no other lesions, 26 had supraspinatus tears, and two had tears in both the supraspinatus and infraspinatus.

The distribution of the tendon tears is shown in Fig. 1. Of the 59 supraspinatus lesions, 44 were full-thickness tears and 15 were tears confined to the deep surface of the tendon. The six infraspinatus lesions consisted of two full-thickness tears and four tears of the deep surface.



**Figure 1** Distribution of the patients by type of subscapularis tendon lesion.

Finally, of the 36 subscapularis tears, 11 were full-thickness tears confined to the upper third, six full-thickness tears of the upper two-thirds, eight full-thickness tears along the entire tendon, and 11 delamination lesions (intra-tendinous in three cases, upper edge in five cases, and deep surface at the lesser tuberosity attachment in three cases).

## Results

### Intra-observer reproducibility

Intra-observer reproducibility of subscapularis tendon evaluation by CT-arthrography was good for the senior orthopaedic surgeon ( $\kappa=0.75$ ) and fair for the orthopaedic surgery resident ( $\kappa=0.65$ ) (Tables 1–3). For both readers, the main differences between the two evaluations occurred for tendons classified as delaminated at the first evaluation, which were often classified in other groups at the second evaluation 30 days later (Table 3). In contrast, tendons classified as intact initially were usually also classified as intact at the second evaluation.

### Inter-observer reproducibility

Agreement among the three readers regarding the subscapularis tendon evaluation was fair (Table 4). R0 was consistently in the 0.5–0.7 range, indicating fair agreement in pairwise comparisons of the three readers.

### Validity and agreement between CT-arthrography and arthroscopy

Major differences were found between the CT-arthrogram interpretations and the arthroscopy findings. Concordance coefficients between the two investigations were 0.44, 0.38, and 0.47 for the senior orthopaedic surgeon, orthopaedic surgery resident, and radiologist, respectively.

### Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)

Specificity of CT-arthrography of the subscapularis tendon, i.e., the proportion of tendons correctly classified as intact,

**Table 2** Intra-observer reproducibility study.

	Reliability coefficient	Interpretation
Reader I	0.75	Good
Reader II	0.64	Fair

Reader I was a senior orthopaedic surgeon and Reader II an orthopaedic surgery resident. These two readers interpreted each CT-arthrogram twice, at an interval of 30 days.

**Table 3** Detailed differences in subscapularis tendon classification between the first and second readings, for tendons classified as delaminated at the first reading.

	First reading (D0)	Second reading (D30)		
	Delaminated	Intact	Delaminated	Full-thickness tear upper 1/3 >, upper 2/3 > or total
Reader I	5	2	1	2
Reader II	15	5	4	6

**Table 4** Concordance coefficient (R0) in pairwise comparisons of the three readers.

	Reader I	Reader II	Reader III
Reader II	0.61	—	—
Reader III	0.505	0.51	—

Reader I was a senior orthopaedic surgeon, Reader II an orthopaedic surgery resident, and Reader III a senior radiologist specialised in osteoarticular imaging. Readers I and II read each CT-arthrogram twice, at an interval of 30 days.

was 0.87, 0.74, and 0.88 for the three readers, respectively (Table 5). Sensitivity (the proportion of tendons correctly classified as abnormal) was 0.75, 0.77, and 0.61. Thus, CT-arthrography lacked sensitivity for detecting subscapularis lesions (particularly when interpreted by the radiologist). In contrast, specificity was good (>80%) for both orthopaedic surgeons: intact tendons were correctly classified in nearly 90% of cases.

The positive predictive value (PPV), i.e., the proportion of abnormal tendons among tendons considered abnormal by CT-arthrography, regardless of the type of abnormality, was 0.87, 0.77, and 0.88 for the three readers, respectively. Thus, overall, the PPV was excellent: lesions seen by CT-arthrography were confirmed by arthroscopy, regardless of their nature. In contrast, determining the type of lesion was more difficult, as suggested by the concordance analysis.

The negative predictive value (NPV), i.e., the proportion of normal tendons among tendons with no abnormalities detected by CT-arthrography, was 0.75, 0.74, and 0.62 for the three readers, respectively. Thus the NPV was not very satisfactory, particularly for the radiologist. In other

words, there was a high false-negative rate: among tendons classified as intact based on the CT-arthrogram, nearly 30% were abnormal arthroscopically for the orthopaedic surgery resident and nearly 40% for the radiologist. For the two orthopaedic surgeons, false-negatives were evenly distributed between delaminations (50% of cases) and full-thickness tears. Surprisingly, for the radiologist, 85% of false-negatives occurred for full-thickness tears. Mistaken CT-arthrogram interpretations of arthroscopically normal tendons were evenly distributed, on average, among the four lesion types (delamination, tear confined to the upper third, tear of the upper two-thirds, and tear along the entire tendon).

### Analysis of the same data after exclusion of delaminated tendons

We computed sensitivity, specificity, PPV, and NPV after excluding the delaminated tendons, given the potentially challenging nature of detecting delamination by CT-arthrography (Table 6). Sensitivity was poor in this analysis confined to tendon tears. Thus, CT-arthrography failed to readily detect subscapularis tears, even those involving the full thickness of the tendon, as the false-negative rate remained high, at 40%. Similarly, when no subscapularis tear was seen by CT-arthrography, arthroscopy showed lesions in 23% to 34% of cases. The high rate of false-negative results (tendons classified as normal despite lesions by arthroscopy) substantially undermined the sensitivity and NPV of CT-arthrography. On the other hand, the low false-positive rate translated into excellent specificity, with CT-arthrography correctly classifying more than 90% of tendons that were intact by arthroscopy.

**Table 5** Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT-arthrography for detecting subscapularis tendon lesions, for each of the three readers.

	Reader I	Reader II	Reader III	Mean
Sensitivity	0.75	0.77	0.61	0.71
Specificity	0.87	0.74	0.88	0.83
PPV	0.87	0.77	0.88	0.84
NPV	0.75	0.74	0.62	0.70

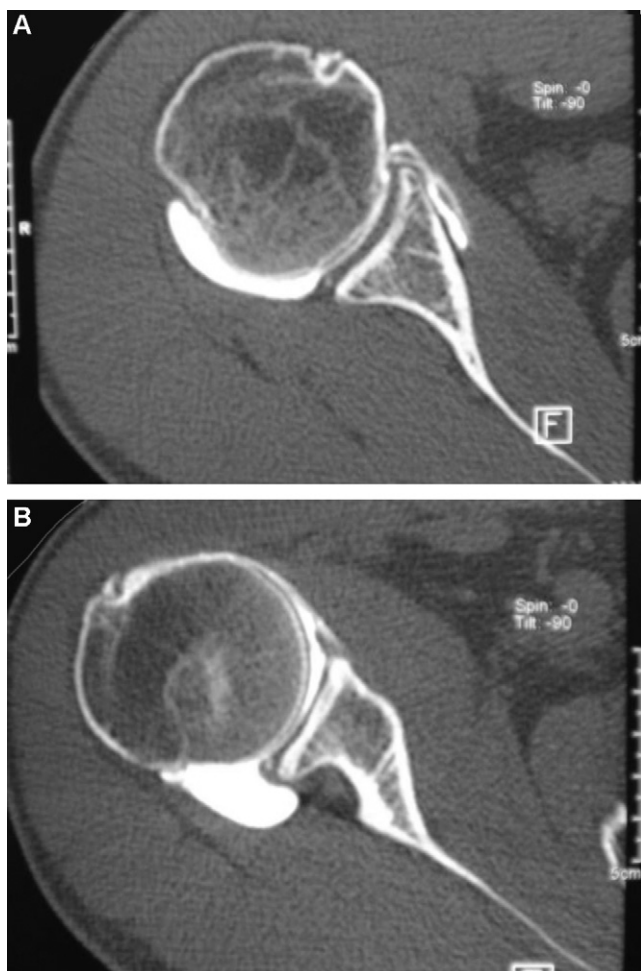
Reader I was a senior orthopaedic surgeon, Reader II an orthopaedic surgery resident, and Reader III a senior radiologist specialised in osteoarticular imaging. Readers I and II read each CT-arthrogram twice, at an interval of 30 days.

**Table 6** Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT-arthrography for detecting subscapularis tendon lesions other than delamination, for each of the three readers.

	Reader I	Reader II	Reader III	Mean
Sensitivity	0.68	0.56	0.52	0.58
Specificity	0.9	0.9	0.92	0.91
PPV	0.85	0.82	0.86	0.84
NPV	0.77	0.71	0.66	0.71

Reader I was a senior orthopaedic surgeon, Reader II an orthopaedic surgery resident, and Reader III a senior radiologist specialised in osteoarticular imaging. Readers I and II read each CT-arthrogram twice, at an interval of 30 days.





**Figure 2** A and B. CT-arthrography, transverse sections in internal rotation (left) and external rotation (right) of a subscapularis tendon that was normal by arthroscopy and correctly diagnosed by all three readers.

Thus, excluding the delaminated tendons failed to improve the sensitivity of CT-arthrography. A large proportion of the diagnostic errors still consisted in classification of tendons with arthroscopically documented full-thickness tears as intact (high false-negative rate).

### Diagnostic errors

Table 7 shows the diagnostic errors by type of subscapularis lesion for each of the three readers. Only 17% of intact tendons were misclassified (Fig. 2). In contrast, 67% of delaminations and 42% of full-thickness tears, on average, were misclassified by CT-arthrography. Diagnostic errors occurred chiefly for abnormal tendons (delaminated or torn). Nevertheless, compared to other lesions, delamination and tears confined to the upper third seemed significantly more difficult to detect, which substantially increased the rate of diagnostic errors (Figs. 3 and 4).

### Discussion

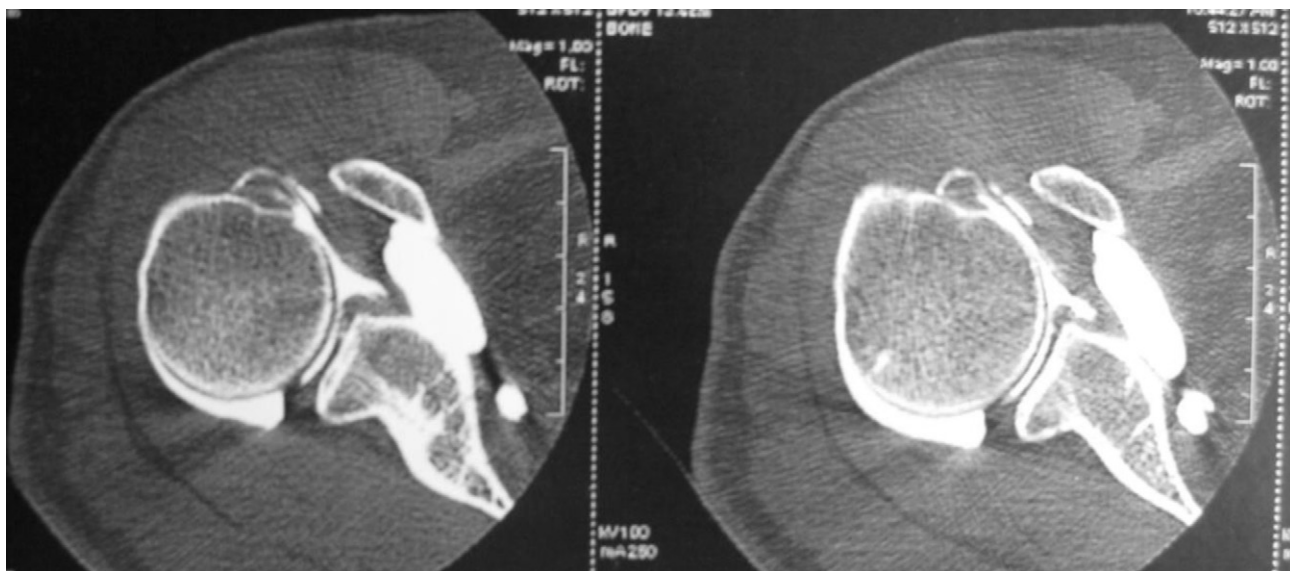
Although isolated subscapularis tendon tears were described by Hauser as early as 1954, they long received little

attention in the orthopaedic and radiological literature [1,2]. Over the last 15 to 20 years, however, several case-series studies evaluated the outcomes after surgical repair of isolated subscapularis tears [3–9]. The clinical and radiological diagnosis of these lesions is described as difficult by most authors [1,10,11]. Despite steady improvements in MR-arthrography, CT-arthrography of the shoulder remains the reference standard for detecting and assessing isolated subscapularis tears [10].

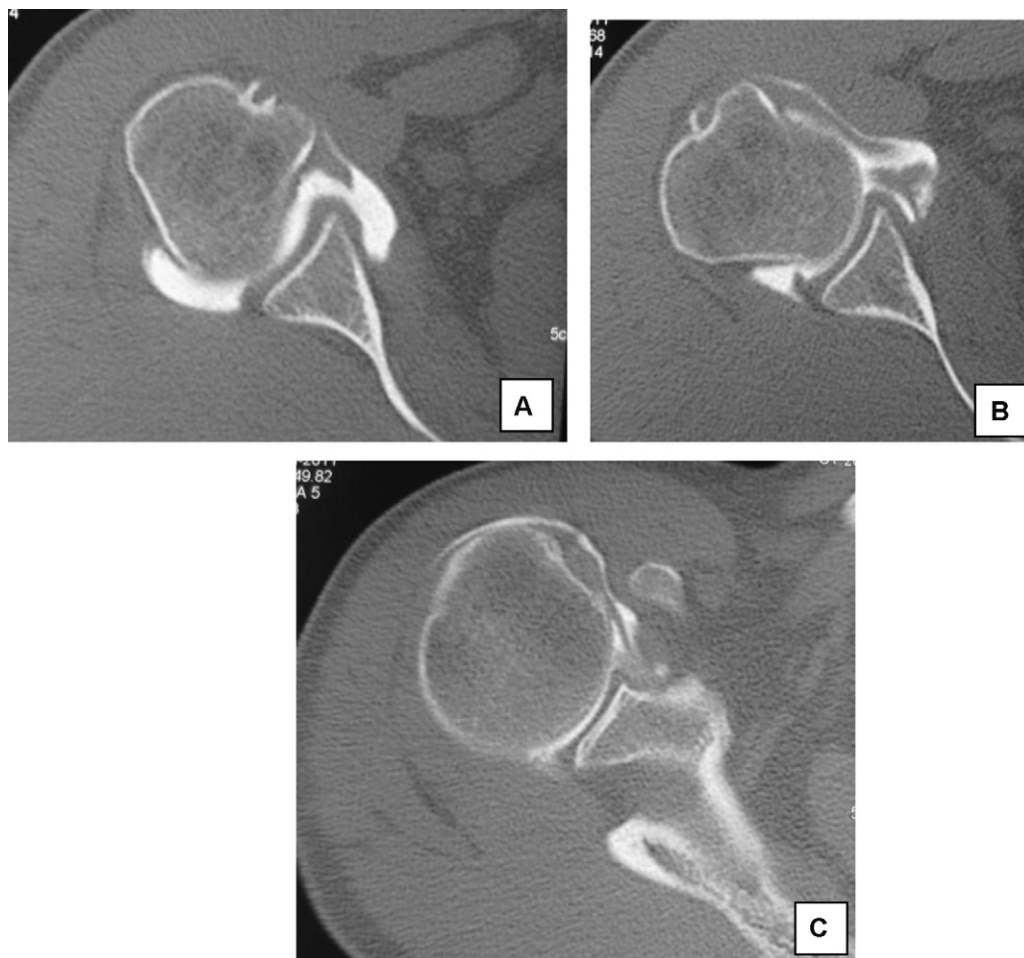
The goal of our study was to evaluate the variability and validity of subscapularis tendon evaluation by CT-arthrography. We are not aware of previous publications addressing this topic in the surgical or radiological literature. The good performance of MRI and MR-arthrography in evaluating the rotator cuff has been documented on many occasions in the recent literature [11,13,14]. However, the validity of MR-arthrography for detecting tears in rotator cuff tendons, and more specifically in the subscapularis tendon, has been assessed in only two studies, by Pfirrmann et al. [11] and Waldt et al. [13]. These two radiological studies evaluated the sensitivity, specificity, and validity of MR-arthrography [11,13]. Although the population studied by Waldt et al. [13] was large ( $n = 275$ ), it was also heterogeneous, since the patients had partial- or full-thickness tears of any of the three rotator cuff tendons (supraspinatus, 65%; infraspinatus, 15%; and subscapularis, 17%). In contrast, the study by Pfirrmann et al. [11] included a more uniform patient population and was designed to assess the reliability and reproducibility of MR-arthrography in evaluating the subscapularis tendon (29 intact and 21 torn tendons). Thus, compared to previous publications, our case-series is larger than the one studied by Pfirrmann et al. [11] and had two comparable groups of shoulders (with intact vs. abnormal tendons), enabling a statistical evaluation of the variability and validity of CT-arthrography for detecting subscapularis lesions.

It has been suggested [10] that CT-arthrography is the reference standard and remains better than MRI and MR-arthrography for evaluating the rotator cuff. However, other published studies [11,13–15] indicate that MRI performs better for diagnosing subscapularis lesions. MRI has high sensitivity and specificity [11,13], provided the tendon is assessed on both transverse images (high sensitivity) and parasagittal images (to eliminate false-positive results, thereby increasing specificity) [11].

In our study, CT-arthrography lacked sensitivity for detecting subscapularis lesions and the high false-negative rate adversely affected NPV. In contrast, specificity was excellent, given the low false-positive rate. In our study, the subscapularis tendon was often evaluated on transverse sections; the absence of a detailed analysis of parasagittal reconstructions probably adversely affected sensitivity, specificity, and the predictive values. Marked variability across the three readers was noted regarding the subscapularis tendon assessment, with  $\kappa$  values consistently lower than 0.61. These data indicate high inter-observer variability in subscapularis tendon assessment by CT-arthrography, similar to that reported for MR-arthrography, with a  $\kappa$  of 0.67 [11]. Our results can be compared to those reported by Charousset et al. [16], who obtained 64.71% sensitivity and 98.17% specificity in a study of 259 CT-arthrograms. Performance was poor for the diagnosis of lesions in the upper third



**Figure 3** CT-arthrography, transverse sections showing a full-thickness tear in the subscapularis tendon that was correctly diagnosed by all three readers.



**Figure 4** CT-arthrography, transverse sections, full-thickness tear confined to the upper twothird with differences in interpretation across the three readers. A and C. In internal rotation, the tendon was considered normal by one of the readers. B. In external rotation, the tendon was considered normal because it was well attached to the lesser tuberosity and the opacity within the tendon was interpreted as a tattoo mark caused by the injection. The diagnosis was a tear in the upper two-thirds of the tendon with a small distal stump.

**Table 7** Diagnostic error rates (%) for each of the three readers according to the arthroscopic appearance of the subscapularis tendon.

	Intact tendon (%)	Delamination (%)	Full-thickness tear, upper third (%)	Full-thickness tear, upper two-thirds or total (%)
Reader I	13	90	73	35
Reader II	26	64	73	43
Reader III	12	46	82	43
Mean	17	67	76	40

Reader I was a senior orthopaedic surgeon, Reader II an orthopaedic surgery resident, and Reader III a senior radiologist specialised in osteoarticular imaging. Readers I and II read.

of the subscapularis on sagittal images (overall agreement, 35%) [16].

Our statistical analysis showed only fair intra-observer reproducibility of the subscapularis assessments done at an interval of 30 days, as well as fair-to-poor agreement between CT-arthrography findings and arthroscopy findings. Several factors probably contribute to explain these poor results. First, subscapularis tears, whether isolated or combined with tears of other tendons (anterosuperior tears) are less common and have received far less attention than supraspinatus and posterosuperior tears. The result may be a lack of diagnostic awareness that may adversely affect the reproducibility of subscapularis lesion assessment. It has been repeatedly emphasised that lesions of the upper third of the subscapularis tendons are difficult to detect by CT-arthrography [1,10,11]. As shown by our study, delamination at the upper edge of the tendon is often difficult to differentiate from an intact tendon or a full-thickness tear confined to the upper third of the tendon. Table 7 indicates that most of the diagnostic errors made by the three readers occurred in patients with delamination or tears confined to the upper third, each of which contributed 30.5% of cases. Consequently, diagnostic errors for these two lesion types explain both the poor agreement between CT-arthrography and arthroscopy and the marked intra-observer and inter-observer variabilities. Although these high variabilities are undeniable, the subjective nature of the CT-arthrographic and arthroscopic assessments can probably affect the level of agreement between these two investigations (taken as a measure of the validity of CT-arthrography for assessing the subscapularis tendon). Thus, subscapularis tendon assessment during arthroscopy of the glenohumeral joint undoubtedly involves measurement and evaluation biases. A study of the reproducibility of arthroscopic subscapularis assessment would probably show inter-observer and intra-observer variabilities, which would then deserve to be measured. These potential variabilities may have influenced the diagnostic performance parameters determined in our study. Although both our study and earlier publications [11,13] used arthroscopy as the reference standard, arthroscopy also involves non-negligible investigation bias, as it may result in underestimation of subscapularis lesions [4,11,17,18]. The method used in our study to classify subscapularis tendon lesions assumes that the lesions develop exclusively in the cranial-caudal direction at the level of the tendon attachment to the lesser tuberosity. This assumption is not verified for lesions located within the muscle belly or at the muscle-tendon junction [11].

Therefore, some lesions may have been underestimated during arthroscopy, supporting the hypothesis that subscapularis tendon lesions are probably far more common than generally thought [10]. Lesions confined to the tendon attachment on the lesser tuberosity may be challenging to detect and assess, for several reasons. First, the anterior location of the subscapularis tendon is an obstacle to complete assessment of the tendon during arthroscopy of the glenohumeral joint. Intraoperative assessment of the appearance and continuity of the subscapularis tendon requires combined antepulsion and internal rotation of the shoulder to expose most of the lesser tuberosity attachment. Nevertheless, Wright et al. [19] reported that an arthroscope introduced into the soft point posterior portal did not allow complete visualization of the lower part of the lesser tuberosity attachment. Furthermore, when a tear is detected by arthroscopy of the glenohumeral joint, assessment of its cranial-caudal extent may be challenging. A full-thickness but tear along only part of the subscapularis tendon height is followed by gradual retraction with filling of the gap by fibrous scar tissue that may either resemble an intact tendon [4,11,17] or make the tear appear smaller than it really is. Intraoperative palpation of the scar tissue, which has none of the mechanical properties of normal tendon [1], can assist in achieving the correct diagnosis. Also useful is the comma sign described by Lo and Burkhart [20], which is created by the combined retraction of the upper edge of the subscapularis tendon, superior glenohumeral ligament, and medial bundle of the coracohumeral ligament.

Achieving the accurate preoperative diagnosis of subscapularis tendon lesions remains a major goal for the surgeon [11], as the nature of the lesion influences the choice of the strategy and techniques. However, this goal is difficult to attain, as shown by the results of our study, because of the various factors discussed above. Nevertheless, the subjective nature of arthroscopic assessment of the subscapularis tendon undoubtedly resulted in bias, and our results should therefore be interpreted with discernment.

## Conclusion

Although CT-arthrography remains the reference standard in several countries, including France, for the preoperative evaluation of rotator cuff tears, substantial variability occurs in the detailed interpretation of subscapularis tendon images. Our data on agreement with arthroscopy indicate suboptimal reliability. Thus, CT-arthrography of the

shoulder may fail to provide valid and reproducible information on the subscapularis tendon.

Our statistical analysis of data on the subscapularis tendon led to the following conclusions:

- the specificity of CT-arthrography is good (i.e., the false-positive rate is low), and therefore the risk of an intact tendon being misclassified as abnormal is very small (Fig. 2);
- sensitivity, in contrast, is low (i.e., the false-negative rate is high), indicating a high risk of missing subscapularis lesions;
- all three readers experienced difficulties in differentiating delaminated from normal tendons; differentiating delaminated from torn tendons, particularly when the tear was confined to the upper third (Figs. 3 and 4); and differentiating full-thickness tears confined to the upper third from normal tendons;
- considerable inter-observer and intra-observer variabilities were documented;
- agreement was poor between CT-arthrography and arthroscopy.

The existence in our study of investigation and measurement biases (most notably related to the subjective nature of arthroscopic evaluation) should temper our conclusions. We still use CT-arthrography as the first-line investigation for the preoperative evaluation of rotator cuff tears, particularly those affecting the subscapularis tendon. However, MRI and MR-arthrography are improving steadily and exhibit good sensitivity, specificity, and agreement with arthroscopy [11]. These investigations can be expected to improve the preoperative detection of subscapularis tendon lesions in the near future.

## Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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